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Development of Regulatory Thermal-Hydraulic Analysis System (RETAS)

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Abstract – *A review is provided of the reasons why the Korea Institute of Nuclear Safety needs improvement of the existing codes employed for a regulatory audit. The proposed new organization of the codes, developed or to be developed, is presented together with illustrative applications. Inspection of the quality assurance activities is planned to ensure the robustness of MARS (Multi-dimensional Analysis for Reactor Safety) code, served as a pivot of the organization.*

I. INTRODUCTION

KINS launched the first 3-years stage project of the national mid- and long-term R&D plan, which aims at structuring a best-estimate (BE) reactor thermal-hydraulic analysis system (hereinafter, RETAS), composed of the computer codes as self-maintainable and technology-independent as practicable. The "best-estimate" descriptor means that physical phenomena would be mathematically modeled in a realistic manner as best as possible, rather than using so-called conservative models.

In this paper, a review is provided of the reasons why the KINS needs improvement of the existing code system employed for a regulatory audit.

II. NEED OF CODE ORGANIZATION IMPROVEMENT

According to the expectation that use of the best-estimate codes would be increased, in 1987 KINS (at that time Nuclear Safety Center) joined the International Code Assessment and applications Program (ICAP), and also participated in the USNRC organized Code Application and Maintenance Program (CAMP) starting in 1992. KINS. Although it has the limitation in modeling of multi-D flow and T-H/kinetics interactions, KINS still regards RELAP5 as robust and applicable to conventional PWRs. Recently [1]

USNRC, at the present, declares the position on RELAP5 [2] that active maintenance will be phased out in the next few years as usage of TRACE[3] grows. There was deliberate consideration on selection of the T-H system code to be served as a pivot of KINS-RETAS, reviewing the merits and demerits of various existing T-H system codes. As a result, utilization of the national R&D product by Korea Atomic Energy Research Institute (KAERI), "development of MARS (Multi-D Analysis for Reactor Safety) code [4]" was recommended. KINS concluded that MARS, if run under a computer operating environment providing a flexible link with other computer codes, is appropriate for purpose of audit analysis.

III. KINS-RETAS AND CONSTITUENT CODES

III.A General Description

The KINS-RETAS is intended to provide a realistic prediction of core and RCS response to the potential event scenarios in Korean PWRs, which range from the normal operating conditions to the accidents threatening core cooling but without progress to core melt. Considering the applicable area and range of MARS as aforementioned, the KINS-RETAS is structured to involve the following provisions:

- General T-H system model to simulate the phenomena and process in RCS, with modeling of RCS and its supporting system components, control system logic elements, etc.,
- Containment T-H model to provide boundary conditions for calculation of LOCA or MSLB mass and energy release to containment,
- Multi-D neutronics model so spatial T-H and kinetics interactions can be simulated, and
- Subchannel models for core DNB analysis and fuel rod performance analysis models

The models in the last clause often depend on the specific fuel design, and are not sufficiently supported in the system code. These are used to confirm in more detail whether specified fuel design limits such as DNB, rod internal pressure and clad oxidation are met for anticipated transients, or the core cooling geometry is maintained for accidents such as LOCA and REA. The proposed KINS-RETAS is shown in fig. 1, depicting the constituent codes and the variables transferred between them.

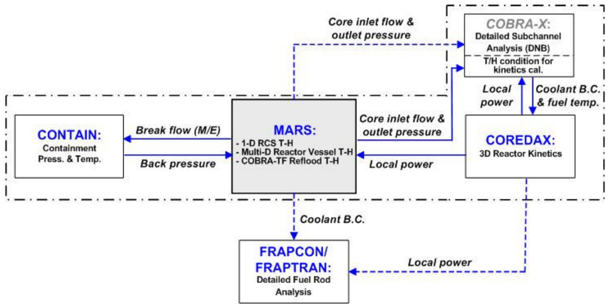

Figure 1 Proposed KINS reactor T-H analysis system

The proposed system is not complete and still preliminary. The system structure in the figure lies on the presumption that the T-H conditions obtained by the subchannel model (the *COBRA-X* in italics) is provided for COREDAX, a multi-D kinetics code based on analytic function expansion nodal (AFEN) method [5].

III.B Application

The backbones of MARS are RELAP5/MOD3.2 and COBRA-TF. MARS development was initially intended to make the most of the merits of the two codes: the former is a versatile and robust system analysis code based on 1-D two-fluid model for two-phase flow, whereas the latter is based on a 3-D two-fluid, three-field model.

Table 1 illustrates the KINS-RETAS analysis process for a representative set of accidents. As indicated in the table, the computer codes are used for an accident analysis, individually or together with others. Therefore, organization of a computer operating environment is devised to do the

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computer code runs by various ways, standalone or coupled runs of more than two codes, as introduced in the next subsection.

Table 1. Illustration of KINS-RETAS accident analysis process

Event types - Representative accidents	Variables of concern	Computer codes used*
RCS overcooling - MSLB	DNB Return-to-power Containment pressure & temperature	MARS↔COREDAX** MARS→*COBRA-X*+COREDAX*** MARS↔COREDAX MARS↔CONTAIN
RCS undercooling - MFLB	RCS boundary pressure	MARS
Reactivity anomaly - Rod Ejection	DNB Fuel stored energy Peak rod power	MARS→*COBRA-X* COREDAX→FRAPTRAN COREDAX
RCS inventory loss - LB-LOCA	Peak clad temperature Oxidation Containment pressure & temperature	MARS MARS→FRAPTRAN MARS↔CONTAIN
Beyond-DBA - ATWS, total loss of feedwater	RCS boundary pressure Rod internal pressure, etc.	MARS MARS→FRAPTRAN

* → one-way data transfer, ↔ data exchange between both, **single couple scheme, ***double couple scheme

III.C Operating Environment

In order to allow the KINS-RETAS analysis process to be flexible, a pseudo simulation environment is introduced, using the current software technology. The descriptor "pseudo" is prefixed to depict the state where one program as deliberately manipulated poses as the main under a simulation environment. The elements of the environment are the pseudo main program, global variable database in a shared memory, graphic user interface (GUI) and executable programs, as seen in fig.4.

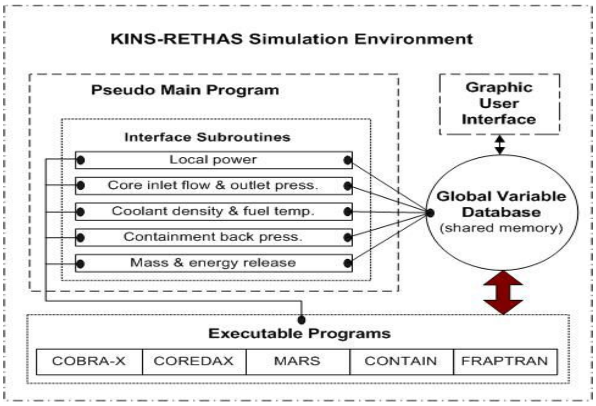

Figure 4. KINS-RETAS Simulation Environment Structure

IV. CODE QUALITY ASSURANCE PLAN

IV.A QA Program and Implementation Plan

The software QA (SQA) is defined as the planned and systematic actions to provide confidence that the software product meets established technical requirements. It includes the process of assuring that standards and procedures are established and are followed throughout the software life cycle. A drafted version of the SQA writer's guidelines for KINS-RETAS codes is now available to be distributed for comments of internal and external stakeholders, and is composed of six chapters:

- Design and development
- Verification
- Validation
- Maintenance
- Application
- Records Management

The general SQA guidelines for thermal-hydraulic system codes are also in a drafted version, based on the previously developed guidelines [6,7,8]. Many parts of the guidelines are applied to development of COREDAX, although it is not a T-H code. Both guidelines are distributed for comments of the internal and external stakeholders this September.

IV.B Verification and Validation

KINS currently prepares the phenomena identification and ranking (PIR) for the postulated accidents in the Korean PWRs. The purpose is to provide a baseline data for development of a V&V matrix. It is identified that MARS has been validated by comparison with various kinds of experimental data [9].

V. CONCLUSIONS

KINS launched the first 3-years stage project of the national mid- and long-term R&D plan in this year. In this project coordinated by KINS, a co-operative work between KINS and KAERI is going on. This project aims at structuring a BE reactor thermal-hydraulic analysis system, composed of the computer codes as self-maintainable and technology-independent as practicable. The universities and other industries also participate in this project for provision of an extensive heat transfer test data bank, development of the 3-D kinetics code and service of the information technology.

Drafted versions of the SQA general guidelines for thermal-hydraulic system codes and the SQA writer's guidelines for KINS-RETAS codes were completed and will be distributed for comments this September. Inspection of the QA records of MARS development is planned, and the PIR work for postulated PWR accidents approaches completion.

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